

On the nature and cause of Specific Language Impairment: a view from sentence processing and infant research

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On the nature and cause of Specific Language Impairment:

A view from sentence processing and infant research

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ABSTRACT

This paper addresses the nature and cause of Specific Language Impairment (SLI) by reviewing recent research in sentence processing of children with SLI compared to typically developing (TD) children and research in infant speech perception. These studies have revealed that children with SLI are sensitive to syntactic, semantic, and real-world information, but do not show sensitivity to grammatical morphemes with low phonetic saliency, and they show longer reaction times than age-matched controls. TD children from the age of 4 show trace reactivation, but some children with SLI fail to show this effect, which resembles the pattern of adults and TD children with low working memory. Finally, findings from the GLAD project have revealed that a group of children at risk for SLI had a history of an auditory delay and impaired processing of prosodic information in the first months of their life, which is not detectable later in life. Although this is a single project that needs to be replicated with a larger group of children, it provides preliminary support for accounts of SLI which make an explicit link between an early deficit in the processing of phonology and later language deficits, and the *Computational Complexity Hypothesis* that argues that the language deficit in children with SLI lies in difficulties integrating different types of information at the interfaces.

Keywords: Specific Language Impairment, on-line sentence processing, infant speech perception, wh-movement, working memory, phonological processing

1. Introduction

In the last 20 years there has been a wealth of studies on the language abilities of children with Specific Language Impairment (SLI) across different ages and languages (Leonard, 1998). This was motivated mainly by two reasons. First, from a clinical perspective, research on SLI was necessary to establish how this disorder manifests itself, and to provide evidence for the nature and cause of the impairment. This could have clinical implications for differential diagnosis, prevention, and treatment. The second reason is related to linguistic theory. SLI was of particular interest because the existence of a disorder affecting language but supposedly not other cognitive domains seemed to provide empirical evidence for modularity.

The majority of studies on children with SLI have investigated language production and comprehension by using off-line methods. These have provided invaluable information about the language strengths and weaknesses of this group of children, and have led to the formulation of several hypotheses to account for the nature and cause of the impairment. However, our knowledge about the nature and the cause of SLI still remains incomplete. This is because of the nature of the group, the limitations of the designs and methodologies used so far and also the fact that none of the existing theories can account for the profile of the children. The present paper addresses the nature and cause of SLI by reviewing research in language processing in children and in infant speech perception, which can bring new insight into the nature and cause of SLI. Section 2 introduces key characteristics of SLI based on off-line studies, Section 3 presents the most important current accounts that have been put forward to explain the nature and cause of SLI, and Section 4 reviews studies on sentence processing in children with SLI. Section 5 discusses the relation between language acquisition and language processing and presents results from the German Language Development (GLAD) Project that provides evidence for a link

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between an early auditory delay and impaired processing of prosodic information and later language deficits in children with SLI. Section 6 pulls everything together by critically discussing the accounts presented in Section 3 in relation to the results from the sentence processing studies in Section 4 and the findings from the GLAD project in Section 5.

2. The phenotype of children with SLI based on off-line studies

Children with SLI are a heterogeneous group of language impaired children. The heterogeneity results from the way they are classified. Their inclusion in this group is not based on the aetiology of the impairment, because this is still unknown, but on a mismatch in their language vs. other cognitive abilities. Children with a language impairment but performance within the norms in non-verbal cognitive tasks are classified as children with SLI. This includes children that differ very much from each other. Some have difficulties only in production, others only in comprehension, and others in both production and comprehension. The hallmark of SLI seems to be problems in the production and comprehension of morpho-syntax. These manifest themselves in different ways depending on the language the children are acquiring. For example, English children with SLI have more problems in the verbal domain (tense/agreement) (Rice and Wexler, 1996) compared to the nominal domain (articles, plural marking) (Bedore and Leonard, 1998); in their production they omit to a greater extent the regular past tense *-ed* morpheme, auxiliaries, copulas, and the 3rd person singular *-s* morpheme compared to articles *a/the* and the noun plural *-s* morpheme. In contrast, Greek children with SLI have difficulties in both the verbal and nominal domain. In the verbal domain, deficits have been reported in the production of subject-verb agreement and to a smaller extent in the production of past tense (Clahsen and Dalalakis, 1999; Mastropavlou, 2006; Smith, 2008). In the nominal domain, Greek children with

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SLI have persistent difficulties in the production of accusative and genitive clitic object pronouns, genitive marking on definite articles and to a smaller extend definite articles (Mastropavlou, 2006; Smith, 2008; Tsimpli, 2001; Tsimpli and Stavrakaki, 1999).¹

The problems children with SLI have are not restricted to the domain of morpho-syntax. Several studies have revealed that children with SLI show phonological problems, have problems in vocabulary acquisition, and show deficits in the syntax-semantics/pragmatics interface. In the domain of phonology, children with SLI show a delay in the acquisition of consonants, and have difficulties in the production of consonant clusters. Early acquired consonants are acquired later in children with SLI, and later acquired consonants cause difficulties even in school-aged children with SLI. Complex syllable structures, such as CCV, are often simplified as CV (Bortolini and Leonard, 2000; Leonard, 1982; Orsolini et al., 2001). In terms of vocabulary acquisition, children with SLI are late in acquiring their first words, and at the early stages of development they use more words to describe objects, substances and animals than actions and properties (Leonard et al., 1982). Pre-school children with SLI seem to use a more limited variety of verbs than language controls, and these tend to be of high frequency (Watkins et al., 1993). Children with SLI have been reported to have problems in naming pictures; they are slower in naming (Lahey and Edwards, 1996), and they make more phonological and semantic errors than their age-peers (Lahey and Edwards, 1999). Of particular interest are studies looking at lexical learning using fast mapping tasks because this can provide a window in the process of word learning. These studies have shown quantitative and qualitative differences between children with SLI, age, and language controls. Differences are less pronounced when the task involves names

¹ For an overview of comprehension problems in children with SLI, see Bishop (1997) and Leonard (1998).

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for unfamiliar objects (Dollaghan, 1987), and are more pronounced when the task involves names for actions and the presentation is in continuous speech, which means that children are not presented with the novel word in isolation, but have to abstract it from the input stream (Rice et al., 1990). Children with SLI also show a slower learning rate than typically developing (TD) children (Windfuhr et al., 2002). A further factor that seems to impact on lexical learning is the number of exposures to the novel words. Children with SLI require a larger number of exposures to the novel words than TD children, and are not as good as TD children in maintaining novel words in long-term memory, particularly verbs (Rice et al., 1994). Finally, several recent studies have shown deficits in the syntax-semantics/pragmatics interface, such as universal quantification, telicity, definiteness, and exhaustivity in *wh*-questions (Roeper, 2004; Schulz & Wittek, 2003).

Apart from problems in morpho-syntax, phonology, vocabulary, and syntax-semantics/pragmatics interface, a large number of studies have shown that children with SLI score lower than age- and language-matched TD children in tasks tapping phonological memory, such as non-word repetition and sentence repetition (Botting and Conti-Ramsden, 2001; Gathercole and Baddeley, 1990; Gathercole, 2006), and suggests that children with SLI have a deficit in phonological memory. In addition, a growing number of studies have revealed that children with SLI process linguistic but also non-linguistic information at a slower rate than TD children (Miller et al., 2001). Furthermore, many studies have shown that some children with SLI also have deficits in non-linguistic abilities, such as motor skills (Hill, 2001) and symbolic play (Johnston, 1994).

Finally, it is crucial to keep in mind that children with SLI are a heterogeneous group of children. The deficits mentioned above are not shared by all children with SLI. This has led to the

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identification of several subgroups of children with SLI. For example, Conti-Ramsden and Botting (1999) have classified children with SLI in six different subgroups: 1) children with a lexical-syntactic deficit, 2) children with verbal dyspraxia, 3) children with phonologic programming deficit syndrome, 4) children with phonological-syntactic deficit syndrome, 5) children with semantic-pragmatic deficit syndrome, and 6) children with grammatical-SLI. Although the linguistic and non-linguistic deficits mentioned above have not been found in all children with SLI, the existence of non-linguistic deficits in some children with SLI challenges the specificity of the impairment and gives rise to several possible scenarios. Language impairment together with subtle deficits in non-linguistic abilities may be the effect of a more general deficit, or it may reflect co-morbidity, i.e., a combination of more than one deficit (Bishop et al., 2005; McArthur and Bishop, 2004). The heterogeneity of children with SLI has important implications for theories on the nature and cause of SLI, which will be discussed in the next section.

3. Accounts on the nature and cause of SLI

Several theories have been developed to account for the profile of children with SLI, and address the issues of the nature and cause of the impairment. These can be classified into three large groups: 1) theories that argue that SLI is caused by a deficit in linguistic representation (Clahsen et al., 1997; Rice and Wexler, 1996; Tsimpli and Stavrakaki, 1999; van der Lely, 1998), 2) theories that argue that SLI is caused by processing deficits (Chiat, 2001; Gathercole and Baddeley, 1990; Joanisse and Seidenberg, 1998; Kail, 1994; Leonard, 1998; Montgomery, 2004) that impact on the development of language, and 3) a theory that argues that SLI is caused by a deficit in accessing and integrating different types of information at the interfaces and relating

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language to other cognitive systems (Jakubowicz, 2003; Jakubowicz and Roulet, 2004). Most theories, apart from the theory by van der Lely (1998), have not been explicitly developed to account for the profile of specific subgroups of children with SLI. However, given that morpho-syntactic deficits are the hallmark of SLI, they aim to account for children with SLI that have problems in morpho-syntax, but may also have other deficits. This includes the subgroups of children with a lexical-syntactic deficit, children with a phonological-syntactic deficit syndrome, and children with grammatical-SLI. An exception is the theory by van der Lely (1998) that has been explicitly developed to account for children with grammatical-SLI, and therefore, does not aim to account for other linguistic and non-linguistic deficits. This section will introduce the most influential current accounts of SLI, which will then be discussed in Section 6 in relation to findings from studies on sentence processing and infant speech perception.

3.1 Representational accounts

The key notion in all representational accounts is that the deficit in children with SLI is at the level of the linguistic representation. However, there is disagreement regarding the locus and cause of the impairment, and in contrast to processing accounts, not all accounts have a developmental dimension.

One of the most influential representational accounts of SLI is the *Extended Optional Infinitive (OI) Account* (Rice and Wexler, 1996) and its new version, the *Extended Unique Checking Constraint (UCC) Account* (Wexler, 1999). The key idea of these accounts is that the

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locus of the deficit in children with SLI relates to the marking of finiteness.² This should contrast to the computational system itself, which should be intact. The cause of the deficit relates to a maturational delay. Children with SLI remain for an extended period of time at the OI Stage, a stage also TD children go through, in which they show optional use of tense marking. According to the more recent version of this account, protracted tense marking omission in children with SLI is caused by the UCC, a principle developed by Wexler within the Minimalist Programme to account for the OI stage in TD children and the profile of children with SLI. According to Wexler, the UCC is a developmental principle that applies in earlier stages of development and constraints checking of the D-feature of the DP. This forces the omission of tense or agreement marking. In TD children, this constraint is supposed to disappear as a function of genetically driven maturation. However, in children with SLI, the UCC is not eliminated at the same age as in TD children, and it is operative for an extended period of time. This account has a developmental dimension because the deficit is linked to a developmental principle.

Two representational accounts posit the locus of the impairment in a less narrowly defined area, in non-interpretable features of functional categories. According to the Grammatical Agreement Deficit Account (Clahsen et al., 1997), the locus of the deficit in children with SLI is *optional* non-interpretable phi-features, i.e. the verb's agreement features. This explains the difficulties children with SLI have in subject-verb agreement in English and German. Similarly, Tsimpli (2001) and Tsimpli and Stavrakaki (1999) argue that the locus of the deficit is in non-interpretable features of functional categories. This account does not constrain non-interpretable

² But see (Rice, 2003) for the delay-within-delay model according to which there is a general delay in children with SLI accompanied by a severe delay in tense marking, which does not entail that tense is the only possible symptom of SLI, but leaves open the possibility of other clinical markers.

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features to optional ones. Functional categories involving any non-interpretable features are predicted to be impaired. It is crucial that in both accounts, the computational system of children with SLI does not differ from that of TD children. Children with SLI are capable of using the operations MERGE, MOVE, and AGREE, which are not optional. Here, SLI is not caused by a maturational delay, but because children with SLI have not yet acquired features that do not have a semantic interpretation. This leaves open the possibility that with time and therapy they may acquire non-interpretable features and the lexical items they map to³.

The *Representation Deficit for Dependent Relationships* (RDDR) (van der Lely, 1998) and its new version *Computational Grammatical Complexity* (CGC) account (van der Lely, 2005) were developed to account for deficits in a highly selective group of children with SLI, children with grammatical SLI. These accounts place the locus of the deficit at the computational system itself. According to the RDDR, the deficit manifests itself in problems with A and A-bar movement. The cause is not in the operation MOVE itself, but in the obligatoriness of movement. To explain optionality in children with SLI, van der Lely postulated the principle Economy 2, which forces overt or covert movement when a feature is unchecked, and ensures that movement is obligatory. According to the RDDR, children with SLI show optionality of movement because they lack the principle Economy 2. The CGC account is very similar to the RDDR in terms of the nature and cause of SLI, but aims to account also for deficits in phonology and morphology by making use of the notion of computational complexity. Children with SLI use the most economic structure, which is according to this model the least complex one.

³ But depending of the timing, this could give rise to critical period effects.

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3.2 Processing accounts

The key notion of processing accounts is that the language impairment in children with SLI results from a general or specific processing deficit which affects the development of language. Therefore, all processing accounts of SLI have a developmental dimension: a processing deficit at an earlier stage of development gives rise to a language deficit at a later stage of development (Karmiloff-Smith, 1998). This distinguishes them from many representational accounts of SLI that posit the locus of the impairment at the linguistic representation per se and do not consider that the development of morpho-syntax is related to general processing abilities and processing of phonological information at an earlier stage of development. The processing accounts differ from each other on the nature of the processing deficit.

According to the *Generalized Slowing Hypothesis* (Kail, 1994), the linguistic and non-linguistics deficits attested in children with SLI result from slower processing of linguistic and non-linguistic information, which is caused by limitations of processing capacity. Within this account, speed determines the amount of work that can be accomplished in a given unit of time. Linguistic and non-linguistic tasks are likely to involve several processes, each of which impact on the Reaction Times (RTs) in the task. This predicts that RTs of children with SLI should differ from those of TD children to the same degree across tasks that require the same number of processes (Miller et al., 2001). This has been borne out in several studies showing that children with SLI have slower RTs compared to TD children of the same age across a wide range of tasks, involving both linguistic and non-linguistic activities (Johnston and Weismer, 1983; Miller et al., 2001; Stark and Montgomery, 1995). This account captures the fact that children with SLI are slower than age-matched control children in linguistic and non-linguistic tasks.

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A second very influential processing account is Leonard's *Surface Hypothesis* (Leonard, 1998). According to this account, SLI is caused by a general processing capacity limitation, which resembles the Slowing Hypothesis and captures linguistic and non-linguistic difficulties related to speed and complexity. In addition, the Surface Hypothesis focuses on the acoustic properties of the target languages, and explains within and between language differences on the acquisition of morphology based on the perceptual properties of each language. The perceptual property that has been considered in this theory is the duration of grammatical morphemes. This accounts for the fact that grammatical morphemes with a brief duration, such as the ones marking tense in English (e.g., *-s*, *-ed*, auxiliaries) are more problematic for children with SLI compared to grammatical morphemes with a longer duration, such as *-ing*. It also accounts for the fact that children with SLI are less accurate with 3rd person singular *-s* than with plural *-s*. Compared to 3rd person singular *-s*, plural *-s* is used more frequently in the sentence final position or at the end of a phonological phrase, and thus, it is significantly lengthened. According to the Surface Account, children with SLI are capable of perceiving word-final consonants and weak syllables. However, when these play a role in a morphological rule, they may be processed incompletely because of processing capacity limitations. This may affect the acquisition process of grammatical morphemes – children with SLI may require more exposure to grammatical morphemes with a brief duration in order to acquire them. Importantly, according to the *Surface Account*, the deficits attested in children with SLI are not caused by a deficit in grammar; similarly to the Slowing Hypothesis, the deficits are caused by processing capacity limitations that affect more complex phonological and syntactic structures.

Gathercole and Baddeley (1990; 1993) and Gathercole (2006) have developed an account according to which the impairments attested in children with SLI are caused by a more localized

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processing deficit, a deficit in phonological memory. This could be due to an imprecise initial segmental analysis, a rapid decay of phonological traces, or a limited phonological memory capacity that could impact on lexical learning and the development of grammar. The idea is that phonological memory is essential for the acquisition of the lexicon and grammar. As far as the acquisition of the lexicon is concerned, new words are initially being stored and rehearsed in phonological memory before they enter long-term memory. If children with SLI have a deficit in phonological memory, then the phonological representations of the words stored may be imprecise, or children with SLI may store fewer items than TD children because phonological traces decay faster or they have a smaller phonological store capacity. This could lead to a smaller vocabulary. A deficit in phonological memory and a limited vocabulary may also cause difficulties in analysing inflected words into stem and affix in order to acquire inflectional morphology, and it may cause difficulties in analyzing sentences in order to acquire the syntax of the target language.

The accounts by Joanisse and Seidenberg (1998) and by Chiat (2001) also implicate the role of phonology in the impairment attested in children with SLI, but without arguing that the locus of the impairment is in phonological memory. Similarly to the *Surface Hypothesis*, according to Joanisse and Seidenberg (1998), SLI is caused by general information processing deficits at a very early stage of development, which affect the development of phonological representations, and can impact on the development of morphology and syntax. In contrast to Joanisse and Seidenberg, Chiat (2001) has argued that SLI is not caused by a general processing deficit, but by an impairment in phonological processing. Chiat's *Phonological Theory of SLI* makes a very explicit link between an early impairment in phonological processing and the development of grammar; impaired phonological processing can disrupt the mapping processes

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through which word and sentence structure is acquired. These processes involve segmentation of the input stream, fast-mapping, and lexical storage, identification of their semantics and their syntactic combinations. Therefore, this theory predicts problems in the development of phonology, that affect lexical and syntactic development in children with SLI.

3.3 Deficit in the performance systems

The last account is the *Computational Complexity Hypothesis* (CCH) developed by Jakubowicz. According to this account, the cause of the language deficit in SLI lies in the difficulties children with SLI have in accessing and integrating different types of information at the interfaces and to relate language to other cognitive systems (Jakubowicz, 2003; Jakubowicz and Roulet, 2004). Although the name of this account is very similar to the name of van der Lely's CGC account, there is a fundamental difference between the two accounts. The CGC locates the deficit in the computation system, whereas the CCH in the interfaces. In addition, the CCH makes use of a metric to define computational complexity that relates to the number of computations involved in the production or comprehension of language. Structures involving more computations are predicted to be acquired later than structures involving fewer computations in both TD children and children with SLI (Jakubowicz, 2003). This hypothesis was supported by data on the acquisition of present, passé composé, pluperfect, gender agreement and wh-questions in French TD children and children with SLI (Jakubowicz, 2003, this volume; Jakubowicz and Nash, 2001; Jakubowicz and Roulet, 2004). For example, *passé composé* is more complex than present tense because present tense requires only the IP, whereas *passé composé* requires an additional functional projection, PastP. Pluperfect is even more complex than *passé composé* because it requires a PastP projection, and it is computed in relation to the main event,

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which is in the *passé composé*. Thus, the CCH predicts that TD children and children with SLI should be more accurate in present tense than in *passé composé* and also more accurate in *passé composé* than in pluperfect. This was borne out in Jakubowicz and Nash (2001), and Jakubowicz (2003). Younger TD children performed better in present tense compared to *passé composé*, and better in *passé composé* than in pluperfect. Children with SLI performed well in present tense forms, but showed optionality in the production of *passé composé* and did not show any instances of pluperfect. Thus, according to this account the profile of children with SLI follows a qualitatively similar but delayed pattern of development with TD children. Crucially, the source of the deficit is in the performance systems and not in the computational system.

4. What does sentence processing research reveal about the nature and cause of SLI

The bulk of research in the language abilities of children with SLI has been based in studies using production tasks off-line comprehension tasks, such as picture selection and picture verification tasks. Production tasks involve not only the computational system, but also the output system of production; similarly, off-line comprehension tasks involve not only language, but also other processes, such as attention, memory, observation, and decision making skills. For example, in off-line sentence comprehension tasks children listen to a sentence and at the end of the sentence they have to select a picture or verify whether or not the sentence matches the picture. To do this task, children have to listen to the sentence, build up the grammatical representation of the sentence and interpret the sentence, store it in memory, observe pictures, and then make a conscious decision. If the task involves pictures or video clips, it also places variable processing capacity demands depending on the number of pictures, events and length of the video clip. As the number of pictures increases, so does the processing capacity required from

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the child in order to decide which picture matches the sentence. Interestingly, despite the complexity of this task, some children with SLI display selectively unimpaired comprehension.

In production tasks, it is very hard to separate errors due to a deficit in the computational system and errors due to a deficit in the production system (but see Leonard et al., 2002). Similarly in off-line comprehension tasks it is very hard to separate errors due to a deficit in the language system from errors due to attention problems, memory, capacity limitations, and biases in decision making. Therefore, based on such tasks it is very difficult to disentangle whether SLI results from a grammatical impairment or from a processing deficit. On-line sentence processing tasks also involve attention and memory resources. However, they usually put less demands on memory compared to off-line comprehension tasks. This is because on-line sentence processing tasks measure how fast participants process words in a sentence in real-time, i.e., before the end of the sentence. Participants do not have to memorise a sentence and then make a conscious decision. In addition, on-line sentence processing tasks are implicit, and do not require a conscious decision related to the grammaticality of a sentence. Therefore, they are more immune to response biases than off-line comprehension tasks.

Sentence processing studies on adults show that mature healthy readers/listeners can utilize and rapidly integrate different types of information (e.g., syntactic, semantic, discourse information) when they read or listen to sentences in real-time (Adams et al., 1998; Altmann and Steedman, 1988; Gibson and Pearlmutter, 1998; Pickering, 1999; Tanenhaus et al., 1995). How does sentence processing develop in children, and are children with SLI capable of using syntactic information when they process sentences in real-time? An increasing number of studies have recently investigated how children process sentences in real-time in order to establish how syntactic processing develops in TD children and children with SLI.

4.1 Processing of syntactic, semantic and real-world information

Montgomery et al. (1990) used a word-monitoring task to investigate how sensitive 7- to 12-year-old TD and language impaired (LI) children are to syntactic, semantic, and real-world information when they process sentences in real-time. Children were presented with a target word, which they had to detect in a sentence. Upon encountering the target word in the sentence, children had to press a button as fast as possible. This provided information about speed of lexical retrieval. In addition, given that children had to detect a word in a sentence, this task could provide evidence of how children process sentences in real-time. Montgomery et al. used sentences without violations, as in (1), sentences that did not conform to real-world expectations, as in (2), and sentences devoid of syntactic, semantic, and real-world information, as in (3).

- (1) Jessie likes to dress in bright colors. His blue *socks* and purple shoes are some of his favorite clothes.
- (2) Some yards are all glass. A pretty *fish* under the table was sleeping in some heavy paper.
- (3) Long were cool nail star. She very *boots* her the got swim green slow ugly dirt bad.

If children are capable of using real-world information on-line, the prediction is that they should be disrupted in sentences that do not conform to real-world expectations (2), and their reaction times (RTs) should be longer compared to the RTs in sentences without any violations (1). Similarly, if they are able to process syntactic and semantic information, their RTs in (3) should be longer than in (1). Montgomery et al.'s study revealed that both predictions were borne out in TD children and also in children with LI. This shows that 7- to 12-year-old TD and LI children

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are sensitive to syntactic, semantic and real-world information when they process sentences in real-time. However, LI children showed overall longer RT than TD children suggesting a slower rate of lexical retrieval.

Sensitivity to syntactic information in TD children and children with SLI was provided also in another word-monitoring study by Montgomery (2000). In this study, children had to detect words at the beginning, middle, or end of sentences. Evidence for the processing of syntactic information would be provided if RTs decreased as words occurred later in the sentence. This is based on the idea that processing is facilitated as we accumulate more sentential information, and therefore, RTs at a later point should be shorter than at an earlier point in a sentence. The study revealed that RTs decreased as words occurred later in the sentence in 7- to 10-year-old TD children and children with SLI of the same age. Similarly to the previous study, children with SLI showed overall longer RTs than TD children, but their sentence processing was facilitated by the accumulation of sentential information.

4.2 Processing of morpho-syntactic information

The processing of morpho-syntactic information in 6- to 10-year-old TD children and children with SLI has been investigated in two studies by Montgomery and Leonard (1998; 2006). These studies used a word monitoring task and compared the processing of sentences involving verbs with low perceptual saliency morphemes compared to verbs with high perceptual saliency morphemes. The 1998 study compared the processing of third-person-singular *-s* and past tense *-ed* with the processing of the present-progressive *-ing*. Children had to detect words following an inflected verb, as in (4), or an uninflected verb, as in (5).

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- (4) Jerry can't wait to get home from school. Everyday he races home and eats *cookies* before dinner.
- (5) Becky loves Saturday mornings. She always gets up early and eat *breakfast* before she watches cartoons.

The prediction is that children will show longer RTs in sentences with uninflected verbs compared to inflected verbs if they are able to process the morpho-syntactic information encoded at the verb inflection. TD children showed longer RTs when both types of inflectional morphemes were missing; in contrast, children with SLI did not show this effect in the sentences with low perceptual saliency morphemes, i.e. there was no difference in RTs between verbs with *-ed/-s* present vs. missing. This suggests that they either do not perceive *-ed/-s* or that they perceive these morphemes, but they cannot build up the syntactic structure on-line, and therefore, they do not show the disruption attested in TD children. Given that *-ed* and *-s* mark tense whereas *-ing* marks aspect, it is possible that the lack of the effect in the processing of *-ed/-s* in children with SLI reflects difficulties with tense morphology and not difficulties with low perceptual saliency morphemes. These results were replicated in the Montgomery and Leonard (2006) study, using as low perceptual saliency morphemes the third-person-singular *-s* and the possessive *-s* and as high perceptual saliency morpheme the present progressive *-ing*. Children heard the sentences as they were produced naturally, and also with acoustic enhancement. The results were very similar to that of the 1998 study irrespective of the enhancement. Children with SLI were not sensitive to the omission of low perceptual saliency morphemes, and acoustic enhancement did not have a beneficial effect.

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4.3 Processing of sentences involving wh-movement – effects of working memory

Three very recent studies used the cross-modal picture priming paradigm to investigate how children process sentences involving filler-gap dependencies in wh-movement, which is one of the most relevant phenomena for linguistic accounts of SLI. Love and Swinney (1997) and Roberts et al., (2006) investigated how 4- to 5-year old and 6- to 7-year old TD children process wh-movement in object relative clauses as in (6).

- (6) John saw [the peacock]_i to which the small penguin gave the nice [1] birthday present t_i
[2] in the garden last weekend.

In this task, children listened to sentences, as in (6) above. At the trace/gap [2] or at a position prior to it (control position) [1], children saw a picture of the antecedent of the trace (filler) (*peacock*) or an unrelated picture (*carrot*) on the computer screen. Upon seeing the picture and while the sentence continued to be heard, children had to perform an aliveness decision for the picture by pressing one of two buttons (animate vs. inanimate). The prediction was that RTs at the trace/gap should be shorter for the antecedent/filler (*peacock*) than for the unrelated picture (*carrot*). This is based on the Trace Reactivation Hypothesis according to which in sentences involving filler-gap dependencies the parser holds the filler temporarily in short term memory; then when it identifies a trace/gap, it retrieves it from short-term memory and sets up a filler-gap dependency by reconstructing the grammatical and semantic features of the filler at the position of the gap. Given that grammatical and semantic features of the filler are activated at the gap, a correct button-press decision on the picture of the filler will show shorter RTs than a button-press decision on the picture of an unrelated picture. This difference should arise only at the position of

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the trace/gap and not at the control position because there is no syntactic dependency between the peacock and the control position. This prediction was borne out in the studies by Love and Swinney and Roberts et al., and suggests that children as young as 4 years old are capable of using structural/syntactic information to construct syntactic dependencies involving wh-movement.

However, the Roberts et al. study also showed that children and adults with low working memory (WM) showed a different pattern from that displayed by participants with high WM. Although children and adults with low WM were able to comprehend the sentences as accurately as the ones with high WM, they did not show shorter RTs for the antecedent at the gap. This shows that WM capacity impacts on the participants' performance in this task. Lack of a reactivation effect at the trace/gap in low WM participants could suggest that they may require more time to retrieve the words from WM in order to establish the syntactic dependency, and thus, the filler-gap dependency was established at a later point in the sentence.

This is not the only study showing effects of WM in the processing of sentences involving wh-movement by children. A study by Booth et al. (2000) looking at the processing of object relative clauses, subject relative clauses, and conjoined verb phrases in 8- to 11-year-old children also showed a different pattern of performance between children with high and low WM. How do children with SLI process sentences involving wh-movement and how does WM impact on their processing pattern?

Using the cross-modal priming paradigm, Marinis and van der Lely (2007) investigated how 10- to 17-year-old children with SLI compared to age and vocabulary controls process stories including wh-questions, as in (7).

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- (7) Balloo gives a long carrot to the rabbit_i. Who_i did Balloo give [1] the long [2] carrot to t_i [3] at the farm?

Children listened to stories that included main clauses followed by wh-questions, as illustrated in (7). Wh-questions were always indirect object *who* questions with preposition stranding, so the trace/gap always followed a preposition. The antecedent of the trace and of the wh-word was always the last word of the preceding main clause (here, *rabbit*). As in the Roberts et al. study, while listening to the sentences children saw a picture and had to press a button for an animacy decision. The picture was either the antecedent of *who* (*rabbit*), or an unrelated picture. In the wh-question, pictures were presented at one of three positions: at the gap [3] (off-set of the preposition *to*), at the off-set of the verb [1], or at a control position [2]. Similarly to the Roberts et al. study, shorter RTs for the antecedent at the gap was predicted to provide evidence that children are capable of establishing a syntactic dependency between the wh-word and the gap. In addition, shorter RTs for the antecedent at the verb was predicted to provide evidence that processing of verbs reactivates their arguments (Nicol, 1996).

Similarly to previous studies in sentence processing by children with SLI, RTs of the children with SLI were overall longer than those of age-matched controls. Age and vocabulary controls showed reactivation at the gap; the children with SLI as a group did not show reactivation at the gap, but they showed reactivation at the verb. In the Marinis and van der Lely paper this was taken as evidence that children with SLI have an impairment at the computational system and instead of establishing a syntactic dependency between the wh-word and the gap, they process sentences involving wh-movement by using lexical/semantic information from the verb. However, there was very large variation in the RTs of the children with SLI, which could be

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attributed to the wide age range. As a group, they did not show reactivation at the gap, but inspection of individual data showed that almost half of them (6/13) showed reactivation at the gap. So, it seems that a large proportion of children with SLI who have persistent grammatical deficits show reactivation at the gap, and thus, process wh-movement similarly to TD children.

For children with SLI who did not show reactivation at the gap this does not necessarily mean that they have an impairment in the computational system. There are several possible alternative explanations for the lack of reactivation at the gap. First, children with SLI may have difficulties to reanalyse or it may have taken them longer to reanalyse. In the experimental sentence '*Who_i did Balloo give the long carrot to t_i at the farm?*' children could have tried to integrate the filler (*who*) at the earliest possible position, i.e., as the direct object of *give*. Then, upon encountering *the long carrot* they would have to reanalyse *who* as the indirect object. Failing to reanalyse or taking longer time to reanalyse may have caused the lack of reactivation at the gap. A second possibility could relate to slower lexical retrieval. Studies using the word-monitoring paradigm have shown that children with SLI show longer RTs which could be linked to problems with lexical retrieval. Cross-modal priming also involves lexical retrieval. Thus, slower lexical retrieval could have caused lack of priming at the gap. Thirdly, lack of reactivation at the trace could be due to low WM. Using the cross-modal priming paradigm, the Roberts et al. study showed no reactivation at the gap in healthy adults and TD children with low WM. There is independent evidence that children with SLI have lower phonological WM than TD children of the same age (Gathercole and Baddeley, 1990; Montgomery, 1995). In addition, the children with SLI in the study by Marinis and van der Lely had lower WM than age-matched controls as measured by the Gaulin and Campbell (1994) test of listening span. Finally, given that children with SLI have a slower speed of processing than TD children, lack of reactivation could have

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been due to the fact that sentences were presented in normal speed. Given that slower speed of presentation facilitates comprehension (Montgomery, 2004), a slower presentation of the sentences could have resulted in reactivation at the gap.

Summarising, the overwhelming majority of studies investigating how children with SLI process sentences using on-line methods have revealed quantitative differences between TD children and children with SLI. Children with SLI show longer RTs than TD children of the same age. This can affect lexical retrieval and the speed of integration of different types of information, and reanalysis, which can explain the lack of reactivation of wh-traces in some children with SLI. However, children with SLI seem to be sensitive to syntactic, semantic, and real-world information when they process sentences in real-time, but they do not show sensitivity to grammatical morphemes with low phonetic saliency. TD children are also sensitive to syntactic, semantic, and real-world information, and at least from the age of 4 onwards they do not differ from adults in the way they process sentences involving wh-movement. But what happens before the age of 4? How does language processing develop in children and what is the relation between language acquisition and language processing?

5. The relation between language acquisition and language processing

Language acquisition is directly related to language processing. In order for a child to acquire his/her native language s/he must be able to analyse the input, and among other things segment words, identify grammatical morphemes, and map formal features to lexical items in order to build up grammar. But language processing also requires some knowledge of the target language that will enable the child to analyse the input string. For example, knowledge that the target language has a trochaic or iambic pattern is crucial for the segmentation of the input string

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into words. Thus, on the one hand language acquisition presupposes the ability to process language, and on the other hand language processing requires some knowledge of the target language (Fodor, 1998). How does the child start to acquire language if the two processes are interdependent?

Recent discoveries in infant speech perception indicate that this paradox may only be apparent. Infants are able to analyse language by using certain cues from very early on. As early as 2 days old, infants are able to discriminate their native language from a foreign language (Christophe and Morton, 1998; Mehler et al., 1988; Moon et al., 1993) and they can also discriminate between two foreign languages from as early as their 4th day of life (Christophe and Morton, 1998; Mehler and Christophe, 1995; Nazzi et al., 1998). The relevant cue for language discrimination seems to be the rhythmic representation of the languages in terms of syllables and vowels (Dehaene-Lambertz and Houston, 1998; Mehler et al., 1996), and reveals the pivotal role of prosodic information at the initial stage of language acquisition.

Prosodic information is not only relevant for language discrimination, but also for segmentation of the input stream and for identifying syntactic boundaries – prosodic bootstrapping to syntax. The prosodic information relevant for segmentation and identification of syntactic boundaries includes pauses, syllable lengthening, and change of fundamental frequency. Infants seem to be capable of using these types of information to detect clause boundaries (Jusczyk et al., 1995; Nazzi et al., 2000), phrase boundaries (Jusczyk et al., 1992; Soderstrom et al., 2003), and word boundaries (Jusczyk, 1999). In addition, they are sensitive to the rhythmic patterns of the target language. English 9 month old infants prefer to segment strings of nonsense syllables into trochaic (strong-weak) rhythmical groups (Echols et al., 1997), which is the predominant pattern in English, and they prefer to listen to bisyllabic words with this pattern

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(Jusczyk et al., 1993). However, prosodic information is not completely reliable for bootstrapping into syntax because there is no one-to-one relationship between prosodic and syntactic structure (Selkirk, 1984). This is particularly the case in the presence of functional words. Despite this, infants seem to be able to recognise unstressed functional words, such as articles, from very early on and before they start producing them (Gerken et al., 1990; Höhle and Weissenborn, 2003), and at the beginning of the second year of their life, infants are able to categorise novel words as nouns on the basis of determiners (Höhle et al., 2004). In addition, in languages with rich morphology, infants seem to be sensitive to inflectional morphology before their second year, and before they start using inflectional morphology in their speech (Blenn et al., 2003).

This research shows that at the initial stage of language development, immediately after birth, children are capable of using prosodic cues to analyse the input stream and process the input. Thus, children seem to be able to process language before they have fully fledged grammatical representations. This suggests that parsing the input may precede and kick start the acquisition of grammar.⁴ Does this entail that children that at an early age do not seem to be able to use prosodic cues in a laboratory setting show later on a delay in the development of language? And how do children with SLI process language when they are babies? Are they capable of using prosodic cues to analyse the input stream and bootstrap into syntax?

These questions were addressed recently in longitudinal studies examining the relationship between infants' early speech processing performance and later language and cognitive outcomes. Two studies investigated the relationship between the processing of vowels and later language outcomes in typically developing children (Molfese et al., 1999; Tsao et al.,

⁴ Although this depends on the notion of the parser, language, and grammar. For a discussion, see Philips (2004).

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2004). The study by Molfese et al. (1999) showed that infants' ERP responses in the processing of vowels predicted their language status at the age of 5 and their reading performance at the age of 8 years, and Tsao et al. (2004) showed a significant correlation between the infants' ability to discriminate a non-English vowel contrast at 6 months of age to vocabulary development at the age of 13 and 24 months as measured by the MacArthur Communicative Development Inventory (MCDI).

Two further studies investigated the relationship between infants' speech segmentation before 12 months, their expressive vocabulary at 24 months, and their linguistic and cognitive skills at the age of 4-6 years (Newman et al., 2006). In the first study, 412 parents of children who participated in infant laboratory studies completed the MCDI, and based on these scores, 119 children with a vocabulary size in the top 15% (average vocabulary of 646 words) and the bottom 15% (average vocabulary of 73 words) of the sample were selected. According to Newman et al., the majority of the children in the bottom 15% qualified for a diagnosis of specific emergent language delay, which is a precursor of SLI. The results from the MCDI were compared to the results from language discrimination, speech segmentation, and prosody tasks. The analyses from the language discrimination task showed that the majority of children from both groups were successful (high MCDI = 85%, low MCDI = 67%) in the language discrimination task at the age of 5 months, but the sample size was small (22 infants). The sample size of the children was larger in the speech segmentation tasks (77 infants). Analysis of the data from these children participating in one or more tasks combined together ranging from 7.5 to 12 months showed that the majority of the high MCDI children (71%), but only 38% of the low MCDI children were successful in the speech segmentation tasks when they were infants. Analysis of each segmentation task separately showed that in two out of the three tasks

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(multisyllabic segmentation and segmentation across talkers at 7.5 and 8 months, sensitivity to phonotactic cues in segmentation at 9 and 12 months, but not segmentation across speaker gender at 10.5 months) this difference was also significant. Analysis of the data from the studies of prosodic preferences at the age of 6 and 9 months showed a success rate of 73% for the high MCDI children and 47% for the low MCDI children; this difference did not reach significance, but this could reflect the small sample size (30 infants). Thus, the findings from the language discrimination and prosodic preference tasks are inconclusive due to the small sample size, but the data from the segmentation tasks suggest that segmentation ability between the age of 7.5 and 12 months may be related to vocabulary at the age of 24 months.

The second study investigated the relationship between infants' segmentation skills, language skills as measured by TOLD3, and cognitive abilities as measured by the Kaufman Brief Intelligence Test at the age of 4 to 6 years in a subgroup of the children participating in the first study (14 with high MCDI and 13 with a low MCDI at 24 months). In this study, children were classified as segmenters (N=10) if they were successful in all segmentation studies they participated in as infants, and as non-segmenters if they were not successful in the segmentation tasks (N=17). The analyses showed no difference between segmenters and non-segmenters in articulation and in their cognitive abilities. All children were within norms in TOLD, but segmenters had a significantly higher score in vocabulary, syntax, and in the overall language composite score than non-segmenters. This suggests that there is a relationship between infants' segmentation skills and the development of vocabulary and syntax. However, the above mentioned studies have included only typically developing children, and thus, their findings may not generalise to impaired populations, such as children with SLI.

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This issue has been addressed in the German Language Development (GLAD) Project (Weissenborn, 2005) which recruited 193 children, divided into two groups, one group of typically developing children and one group of children with family history in language impairment (Penner et al., 2006). To date, three studies have been published from this project. A study by Weber et al., (2005) investigated the processing of prosodic information (word stress) in two groups of 5 month old infants, 9 infants at risk for SLI and a control group of 9 typically developing infants. Infants were grouped retrospectively into TD vs. at risk for SLI based on two parental questionnaires (ELFRA I and II) at the ages of 12 and 24 months. The children at risk for SLI showed very low word production. Weber et al. compared the performance of the two groups on a Mismatch Negativity (MMN) Task at 5 months involving processing of prosodic information. As mentioned above, word stress is pivotal for word segmentation, and children acquiring English and German have a preference for the trochaic pattern, which is the most frequent pattern for bisyllabic words (Jusczyk et al., 1993). In the Weber et al. study, infants listened to CVCV non-words with a trochaic or an iambic pattern in two runs. In one run 5 out of 6 non-words had a trochaic pattern and functioned as standard items, and 1 out of 6 non-words had an iambic pattern and functioned as deviant items. In the other run, the proportion of non-words followed the opposite pattern (iambic pattern was the standard and trochaic pattern was the deviant). Results showed that compared to the TD children, the group of children at risk for SLI showed a significantly reduced MMN amplitude in response to trochaic stress pattern. This indicates that children with very low word production at 12 and 24 months cannot discriminate the most frequent prosodic pattern in the language they are acquiring (trochaic pattern) when they are 5 months old, and suggests that children at risk for SLI have a reduced ability to detect prosodic cues during early stages of development.

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In a second study from the GLAD project, Höhle et al. (2006) investigated the relationship between word processing at 19 months using the intermodal preferential looking paradigm and language performance at 30 months using a standardised test assessing comprehension and production (SETK2). This study included seventy one children from the GLAD study. Based on the results from SETK2 at 30 months, the children were divided into two groups, one group of 50 TD children, and one group of 21 children that scored below 1 SD from the mean in at least two subtests of SETK2, and were therefore classified as children with low language performance. Then Höhle et al. compared the performance of the two groups in the preferential looking paradigm at the age of 19 months. In this task, children saw two pictures on a computer screen (e.g. a picture of a table and a picture of a comb) and heard a sentence with a target noun as its final word (e.g. *Wo ist der Tisch?*=where is the *table*). The target noun either corresponded to one of the two pictures (e.g. *Tisch=table*, *Kamm=comb*) or it was a mispronunciation of the word that corresponded to one of the two pictures which resulted from changing the place of articulation of the initial consonant (e.g. *Tamm* instead of *Kamm=comb*, *kisch* instead of *Tisch=table*). The preferential looking paradigm measures the children's looking time. The children's eye movements were recorded prior, during, and after the auditory stimuli, and the prediction was that after the word was presented children would show increased fixations to the target picture when the pronunciation of the word was correct, but not in the mispronunciation condition. This effect was attested in the TD children, but not in the group with low language performance. The low language group showed, in contrast, increased fixations to the target picture in the mispronunciation condition. These findings suggest that there is a relation between early phonological specificity at 19 months and language comprehension and production at 30 months. The findings from the TD children show that at the age of 19 months they have

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specified phonological representations for familiar words, and are able to differentiate between these and phonological forms that deviate in one phonological feature in the initial phoneme. The pattern of results of the children with a low language score is more difficult to explain, especially their increased fixations for the mispronunciations. Höhle et al. suggest that the low language children may have instable phonological representations and they consider the mispronunciations as a possible variant of the correct word, which causes a novelty effect and increased fixation times. However, if they considered the mispronunciations as possible variants it is unclear why this should cause a novelty effect. Leaving this aside, the important finding from this study is that word processing at 19 months can predict language comprehension and production at the age of 30 months.

The third study investigated the maturation of the auditory pathways in 61 infants from the GLAD project using Brainstem Evoked Response Audiometry (BERA) (Penner et al., 2006). Infants were tested with this method four times, at 2, 6, 14, and 17 months of age. The BERA data from the age of 6 months were then correlated with the results from two parental questionnaires, ELFRA I at 1;6 years, ELFRA II at 2;0 years, and the standardised test SETK2 assessing comprehension and production at 2;6 years. This showed significant correlations between the values of the interpeak latencies of waves I-V at the age of 6 months and the results of both parental questionnaires and sentence comprehension at 2;6. Then based on the results from ELFRA II at 2 years and the latency values from BERA at 6 months, infants were divided into a group with slow and a group with fast latencies. Comparison with the results from BERA at 2, 14, and 17 months revealed that the difference in latencies between the two groups attested at 6 months was also present at 2 months, but this difference ceased to exist at 14 and 17 months, suggesting that the children with slow latencies caught up with the rest of the group. However,

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results from ELFRA I, II, and SETK2 showed that the infants with slow latencies at 2 and 6 months had a significantly lower vocabulary at 1;6 and 2;0 years and a lower score in language production at 2;6 years compared to the infants with fast latencies. This suggests that slow maturation of the auditory pathways during the first months of life which are not detectable after the age of 14 months may cause delays at later stages of language development affecting the development of vocabulary and grammar. What do these findings and the findings from the sentence processing studies suggest about the nature and cause of SLI, and how do they relate to SLI theories?

6. Relating findings from processing studies to theories on the nature and cause of SLI

The GLAD project is the first project to provide a direct link between an auditory delay and impaired processing of prosodic information in the first months of life and a later language delay and risk for SLI. Since this is a single project and the published studies so far have presented data from different subgroups of the GLAD project, their findings should be interpreted with caution and need to be replicated with a larger group of children. However, the data do suggest that some children with a language delay and at risk for SLI may have a history of an auditory delay and impaired processing of prosodic information in the first months of their life, which is not detectable later in life. Results from on-line sentence processing studies reveal that children with SLI are sensitive to syntactic, semantic, and real-world information, are sensitive to grammatical morphemes with high phonetic saliency, and some children with SLI can also process wh-dependencies similarly to TD children. However, children with SLI show slower speed of processing than TD children, they have difficulties processing grammatical morphemes with low phonetic saliency, such as past tense *-ed*, 3rd person singular *-s* and possessive *-s*, and

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some children with persistent grammatical difficulties fail to reactivate the antecedent of the trace in wh-filler-gap dependencies. How can theories on the nature and cause of SLI account for these findings?

According to the Extended Unique Checking Constraint Account (Wexler, 1999), SLI is caused by a maturational delay affecting a developmental principle that does not allow the D-feature of the DP to be checked more than once. This account describes accurately the facts regarding tense marking in English children with SLI, and is compatible with the findings from on-line processing studies that children with SLI are sensitive to syntactic, semantic, and real-world information. It is also consistent with the fact that children with SLI show reduced speed of processing in language tasks. Given that tense marking is involved in all declarative sentences, limited speed of processing could result from the UCC. However, this account fails to capture all other linguistic difficulties attested in children with SLI, the results from the on-line processing studies regarding sensitivity to low phonetic saliency morphemes, and the results from the infant studies. Interestingly, difficulties with tense marking in English are not only attested in children with SLI, but also in many other populations, such as oral deaf children (de Villiers et al., 1994), and children with English as a Second Language (L2) (Paradis, 2005; Paradis, 2008; Marinis & Chondrogianni, under review). Although these two populations show a similar profile to children with SLI in terms of tense marking, the cause of their language difficulty is not related to a maturational delay, but to reduced exposure to English.

The accounts by Clahsen et al. (1997) and Tsimpili (2001) capture a larger number of phenomena cross-linguistically than the account by Wexler, and are developmental accounts because the deficit is defined in terms of difficulties acquiring a specific set of features and lexical items. However, this does not explain *why* children with SLI have a difficulty acquiring

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non-interpretable features, and also these theories cannot account for the difficulties children with SLI have in other linguistic domains, such as phonology, and vocabulary acquisition. Reduced speed of processing in language tasks and difficulties with the low phonetic saliency morphemes tested in the Montgomery and Leonard studies could result from difficulties accessing non-interpretable features. However, these theories do not predict impaired processing of prosodic information at an early stage of development. Finally, given that according to these accounts the deficit is not due to a developmental delay, it is unclear why children with SLI start developing language late.

Similarly to the accounts by Clahsen et al. and Tsimpili, the RDDR (van der Lely, 1998) and the CGC (van der Lely, 2005) argue that SLI is not caused by a maturational delay, but by a deficit. However, in contrast to Clahsen et al. and Tsimpili, the deficit is not caused by features that have not been acquired yet, but by a defective computational system. This captures most syntactic deficits of English children with SLI. However, there does not seem to be any independent evidence that a principle, such as Economy 2 exists, which seems to be a theoretical construct designed to describe the optionality attested in the language of children with SLI. Furthermore, Economy 2 seems to fail short of explanatory adequacy. It is not clear why it is missing in children with SLI. The CGC makes use of the notion of computational complexity to explain the difficulties attested in the domains of syntax, morphology, and phonology, but it fails to define complexity in a principled way. In addition, it predicts difficulties that are not attested in children with SLI. For example, if children with SLI have an impairment in the computational system affecting movement, children with SLI should have difficulties processing wh-questions. This was not borne out in the Marinis and van der Lely (2007) study because almost half of the children with SLI showed reactivation at the gap. Finally, the RDDR and the CGC are not

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developmental accounts. Therefore, they do not account for the late onset of language acquisition and their impaired processing of prosodic information at an early stage of development.

The *Computational Complexity Hypothesis* (Jakubowicz, 2003; Jakubowicz and Roulet, 2004) and accounts of SLI that make an explicit link between an early deficit in the processing of phonology and later deficits in phonology, syntax, and the lexicon (Chiat, 2001; Gathercole and Baddeley, 1990; Joanisse and Seidenberg, 1998; Kail, 1994; Leonard, 1998) can better account for the profile of children with SLI, and the recent results from on-line processing and infant studies. This is because first, they do not pose the deficit in children with SLI in the computational system of language, but at the interface between language and other cognitive systems. This would affect language, but could also affect other cognitive systems and could account for linguistic and non-linguistic deficits of children with SLI. Second, these accounts can easily accommodate the findings from the infant studies. In fact, the results from the GLAD project match perfectly with the predictions of Joanisse and Seidenberg (1998) and Chiat (2001) because these two accounts predict that an early deficit in the processing of phonology can impact on later development. According to Chiat (2001), a deficit in the processing of prosodic information can have an impact on the mapping processes, which could in turn affect phonological, lexical and syntactic development. Reduced speed of processing of language could either result from a deficit in the processing of prosodic information or it could result from an underlying neuro-maturational delay that may cause the slow maturation of the auditory pathways (Penner et al., 2006) and can impact on the development of phonological and working memory (Gathercole, 2006; Montgomery, 2004). A deficit in phonological memory could then impact on the development of grammar. For children to acquire inflectional morphology, they should be able to analyse inflected words into stem and affix, and to acquire syntax they should

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be able to analyse sentences on-line. A deficit in phonological memory could affect their ability to analyse the input stream, map formal features to lexical items, and build syntactic structure in real-time.

To date the *Computational Complexity Hypothesis* (Jakubowicz, 2003; Jakubowicz and Roulet, 2004) and the accounts of Joanisse and Seidenberg (1998) and Chiat (2001) are the most plausible accounts for the nature and cause of SLI, and they can accommodate very well recent findings from on-line processing research and research in infant speech perception. However, further research is required first to replicate the findings from the on-line processing and the GLAD project with a larger group of children with SLI, and second to determine the relationship between the maturation of the auditory pathways and the processing of prosody, the relationship between the development of processing of prosodic, morphological and syntactic information, and the impact of the maturation of the auditory pathways on the development of phonological memory, and working memory.

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